ADMINISTRATIVE INFORMATION

1. **Project Name:** In-Situ, Real Time Measurement of Melt Constituents in the Aluminum, Glass, and Steel Industries

2. **Lead Organization:** Energy Research Company
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3. **Principal Investigator:** Robert De Saro
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4. **Project Partners:** Commonwealth Aluminum, Minesh Parikh,
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5. **Date Project Initiated:** 1/8/99

6. **Expected Completion Date:** 12/31/03

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:**

The main objective of this project is the design, construction, and testing of a new sensor capable of measuring the elemental constituents of molten metal in-situ and in real time. The goal of the first year effort was the testing of an instrument capable of measuring the elemental constituents of molten aluminum inside a laboratory scale furnace. The goal of the second year effort was the testing of a probe in a pilot scale aluminum furnace. The goal of the third year effort was the design and construction of a probe for installation at a commercial aluminum plant. This installation has resulted in a permanent, commercially operating, continuous measurement System.

8. **Technical Barrier(s) Being Addressed:**

In the production of aluminum, steel, and glass, composition of the material is closely controlled in order to ensure material properties consistent with expectations. Since the composition can only be changed while the material is in a molten state, current practice is to remove a small sample of molten material from the furnace for analysis by a laboratory. The results of the analysis, for example, the percentages of Mg, Mn, Cr, Fe, etc. in an aluminum melt, are used by the furnace operator to add or remove elements from the melt in order to bring the composition to within the desired material's specification. Usually multiple analysis are performed on the same melt.

There are a number of inefficiencies and problems with this method. By sampling the material off-line, the furnace idles and productivity comes to a halt while the material is transported to the laboratory and the analysis is performed.

Second, the material that is removed from the melt may not be representative of the entire melt. If alloying materials were added to the melt and the melt was not sufficiently mixed, the melt may be

inhomogeneous, and changes done on the basis of the analysis of the sample may not bring the material into specification.

These two problems lead to excessive melting time, quality control problems, wasted feedstock, increased energy used and emissions, and product that may need to be remelted.

9. **Project Pathway:**

Our concept employs laser induced breakdown spectroscopy (LIBS) which uses a laser and spectrometer to measure in-situ, and in real time, the constituents of the melt in a process furnace (See Figure 1) to solve the above mentioned problems. The laser is repetitively fired through a fiber optic cable. The fiber optic is placed in the melt during furnace operation. A small amount of melt absorbs the laser light and is rapidly irradiated. The resulting light, which is a function of the individual elements present, is returned to the spectrometer which resolves the individual wavelengths and their amplitudes. Each wavelength indicates the element that is present, and its amplitude the element's concentration.

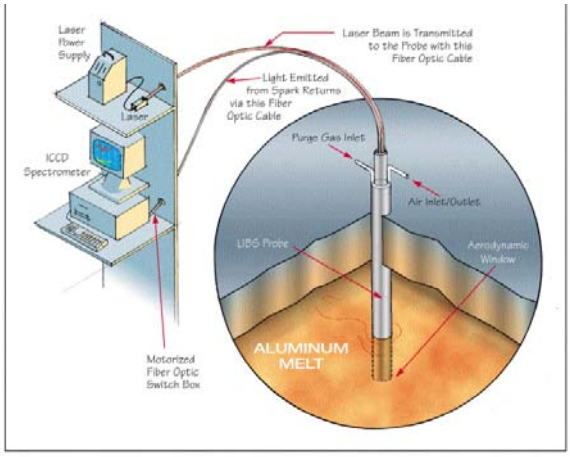

Figure 1 - Schematic of LIBS System Installed at Aluminum Plant

10. **Critical Technical Metrics:**

- Conduct full-scale continuous demonstration at an aluminum plant.
- Achieve continuous measurement of melt chemistry
- Achieve an accuracy comparable to current methods - ± 5% relative error on elemental concentrations of 0.05% or higher.
- Measure all elements of interest – Si, Al, Mg, Mn, Cu, Cr, Na, and Zn.
- Achieve low maintenance.
- Provide single push-button operation with no operator training required.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:**

- Developed Calibrationless (C-LESS™) method of determining elemental concentrations from raw spectra without the need for costly calibration curves.
- Developed a probe for use in molten aluminum
- Achieved desired accuracy
- Installed full-scale, continuously operating system at Commonwealth Aluminum
- Measured all elements of interest.
- Single push button operation, with no operator training required, achieved.
- System classified as eye safe
- Patent applied for in US, Canada, Japan, and Europe.
- Established licensing agreement for worldwide sales of system.

A photo of the system installed at Commonwealth Aluminum (Uhrichsville, OH) is shown in Figure 2. The photo on the left shows the probe being inserted in Commonwealth's melt, and the photo on the right shows the cabinet housing the LIBS equipment.

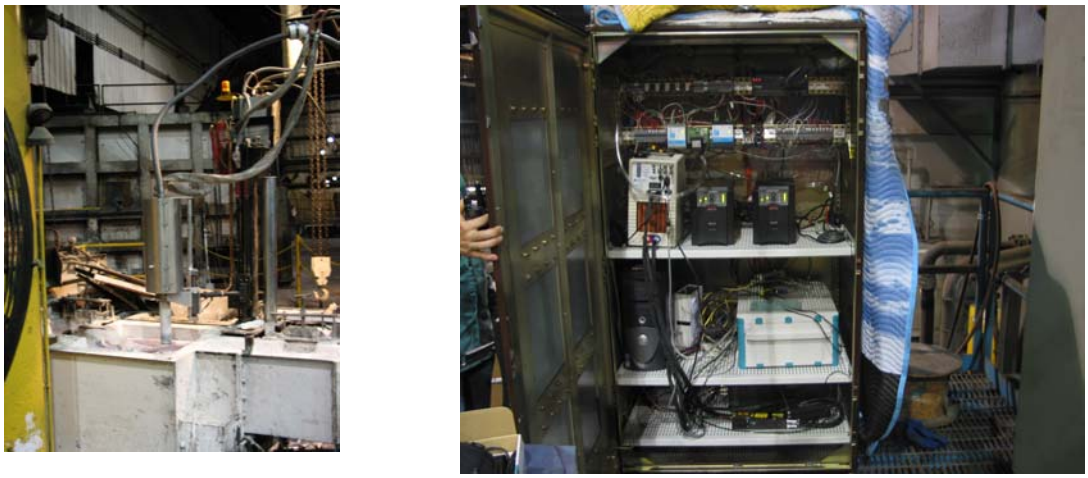

Figure 2 - LIBS Probe in Commonwealth's Melt (Left) and Cabinet Housing LIBS Equipment (Right)

Table 1 shows the LIBS data as compared to the traditional method typically used at aluminum plants. The comparison shows excellent accuracy agreement for concentrations at or above 0.1%.

Table 1 - Commonwealth Data

	Al	Cu	Fe	Mg	Mn	Si	Cr
LIBS Average	97.87	0.17	0.65	0.47	0.52	0.28	0.04
Commonwealth Average	97.56	0.18	0.65	0.49	0.56	0.30	1.05
% Difference	0.32	5.6	0.0	4.1	7.1	6.7	20.0
LIBS RSD	0.09	5.0	4.87	11.61	4.54	6.29	5.52
Commonwealth RSD	0.03	3.51	3.65	1.53	3.57	2.25	2.17

12. Future Plans:

The full-scale commercial installation at Commonwealth has been completed. Energy Research Company (ERCo) will now continue its commercialization efforts. Solios Thermal was granted a license to market the system worldwide to the aluminum industry. Recently, two Solios employees were tasked with the responsibility of selling the instrument in the US. ERCo is supporting their efforts. In addition, ERCo is applying the technology to the following other industries:

- Glass Batch
- Coal properties
- Molten Steel
- Molten Glass

13. Project Changes:

None

14. Commercialization Potential, Plans, and Activities:

The end use application of this project is a sensor that measures the elemental concentrations of molten aluminum in situ and in real time. Solios Thermal will sell the system to the Aluminum industry, with ERCo providing engineering support, instrument development, instrument fabrication, and maintenance services.

15. Patents, Publications, Presentations:

ERCo has one LIBS related patent pending in the US, Europe, Japan, and Canada. Two papers were presented – One at the TMS 2003 Annual conference and another at the 18th International Forum on Process Analytical Chemistry in January 2004.